TJHSST Computer Systems Lab Senior Research Project
Excursions into Logic Based Computation using Conway's Game of Life
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Abstract

Conway's Game of Life is a set of rules in a two dimensional cellular automata grid. Specifically, the Game of Life allows cells to have two states and provides them with eight neighbors. The rules state that between one generation and the next, live cells with two or three live neighbors live on, and dead cells with exactly three live neighbors come to life. This ruleset was specifically chosen by John Conway for the ability to create stable patterns as well as the difficulty of creating patterns which grow infinitely. This difficulty was rather quickly overcome by Bill Gosper's glider gun, which opened up the ability to create computational devices such as logic gates. This project endeavors to use this functionality to create a computational device in the Game of Life.

1 Introduction - Elaboration on the problem statement, purpose, and project scope

1.1 Scope of Study

In terms of coding in computer programming languages, the scope of study will include the implementation of a Game of Life simulator. Though this is no new feat, it is necessary to create one for this project as it will involve the construction of large and complex designs within the Game of Life. There are no implementations of the Game of Life available which are easily useable for constructing large patterns within the Game of Life. In addition, a program used to search for reactions between gliders and spaceships within the Game of Life will have to be implemented.

The scope of study goes beyond the coding, however, as the purpose of this project is to create a logic based computing device within the Game of Life. This will require research into common reactions in the Game of Life as well as previous creations within the Game of Life.

Specifically, the first objective of this project is to develop a calculator implemented with the Game of Life. This will require the development of algorithms useable and relatively efficient in the Game of Life. After a four function calculator is created, functions such as exponentiation will be added, though one major failing of any Game of Life implementation is the difficulty of representing numbers not in the whole number set. This is possible, however, and will be another extension of the computing device.

1.2 Expected results

The prospective result of this project is the development of two flexible programs, one for constructing and running designs in the Game of Life the other for searching for reactions and oscillators in the Game of Life world, and a design within the Game of Life which will take specific inputs and return the desired output.

In doing this project, I will develop a flexible Game of Life editor, which will be the major new contribution to the field. The underlying ideas are not new; one man spent a number of years developing a Turing Machine extensible to universality in the Game of Life. It is not feasible to design that in the course of this project, though it will be necessary to create designs for specific purposes which may be new.

1.3 Type of research

This project involves pure applied research. None of the problems that this project attemts to address have not been tackled before and the trick will to find, using computer searches, patterns which have the functionalities that will be required. This will all be new to me, but it is the nature of cellular automata that fundamental understanding is impossible to achieve: cellular automata are noteable precisely for the ability to defy prediction.

2 Background and review of current literature and research

As previously mentioned, a man by the name of Paul Rendell spent a number of years developing a finite Turing machine extensible to universality in Conway's Game of Life. His project is the extreme of complexity, but others have created logic gates, most notably Andrew Adamatzky's LogiCell, presented in his *Collision Based Computing*. With respect to Rendell, two rather large extensions are possible on his work. Firstly, he created his Turing machine with extensiblity to universality specifically in mind, meainging one could use his Turing machine as a template to create a universal Turing machine. In addition to that, Rendell is currently working on create a stack cell generator, which would generate tape for his Turing machine, effectively giving it infinite tape.

This project differs from the other projects in that it endeavors to create a product, a calculator, which must have a useable user interface. My approach differs from that of Adamatzky's because I will endeavor to create one multipurpose design which will perform all of the functions and give understandeable outputs, as opposed to creating a number of different circuits, the outputs of which would hinge on the state of a specific cell at some arbitrary time.

3 Procedures and Methodology

In order to complete my task I will have to fully develop my Game of Life editor, write a program to search for useful patterns and reactions, and put everything together. During the second quarter I will be primarily concerned with the editor and the search program, the third being devoted to the creation of the computational program.

It is ironic that it is difficult to produce helpful visuals for cellular automata, which are inherently visual. However, I can provide a visual of the interface and the circuitry. In addition, it might be helpful to make visuals which show the runtime behavior of each of the functions. The collection of this data is rather easy; cellular automata have an inherent dimension of time, the generation.

Analysis for the functioning of my program will be rather easy; I will just take the space needed and the time required to perform any function. Testing my program will be done mainly with the search function, which will provide me with patterns for use in my project. The purpose for using a search program is to come up with patterns that will do exactly what I want, and theoretically render program testing unnecessary. However, when I have created the calculator, testing will be rather simple; every inputs will by quickly verifiable with an electronic calculator. The design will necessarily be compartmentalized, so I can only test my program by testing specific parts of it.

The major requriement that I will impose upon my program is that it work. I have no idea how much space it will take to make the patterns necessary for computation, and no idea how much time it will take to perform computation.

4 Expected Results

At the end of this project, I can expect a functioning computational device which computes solely in the Game of Life. My analysis of this calculator will have two dimensions - time and space. I can optimize the number of generations it takes to perform any computation and reduce the amount of space it takes to do so.

The most useful contributions that I will be able to make at the end of this project will be my programs for editing in and running the Game of Life, and my program for searching for useful patterns.